Attaining Tier 2 Emissions Through Diesel Engine and Aftertreatment Integration - Strategy and Experimental Results

R. Aneja, B. Bolton, N. Hakim, Z. Pavlova-MacKinnon

Detroit Diesel Corporation, DaimlerChrysler Powersystems

The feasibility of diesel engines to meet the stringent emissions regulations of 2007 and beyond is an important consideration for light trucks and other personal transportation vehicles. Integrated engine and aftertreatment systems have been developed at Detroit Diesel Corporation for multiple engine and vehicle platforms. Tier 2 emissions technologies have been demonstrated with significant fuel economy advantage compared to the respective production gasoline engines while maintaining excellent drivability.

The performance and emission results were achieved by integrating advanced combustion strategies with prototype aftertreatment systems. The system development methodology included the integration of experimental and digital tools. Further, the experimental development approach included systematic testing on steady-state dynamometer, transient dynamometer and chassis dynamometer test beds.

DAIMLERCHRYSLER

DaimlerChrysler Powersystems

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"Dieselization" of Vehicle Fleet Offers Significant Reduction to U.S. Transportation Energy Use

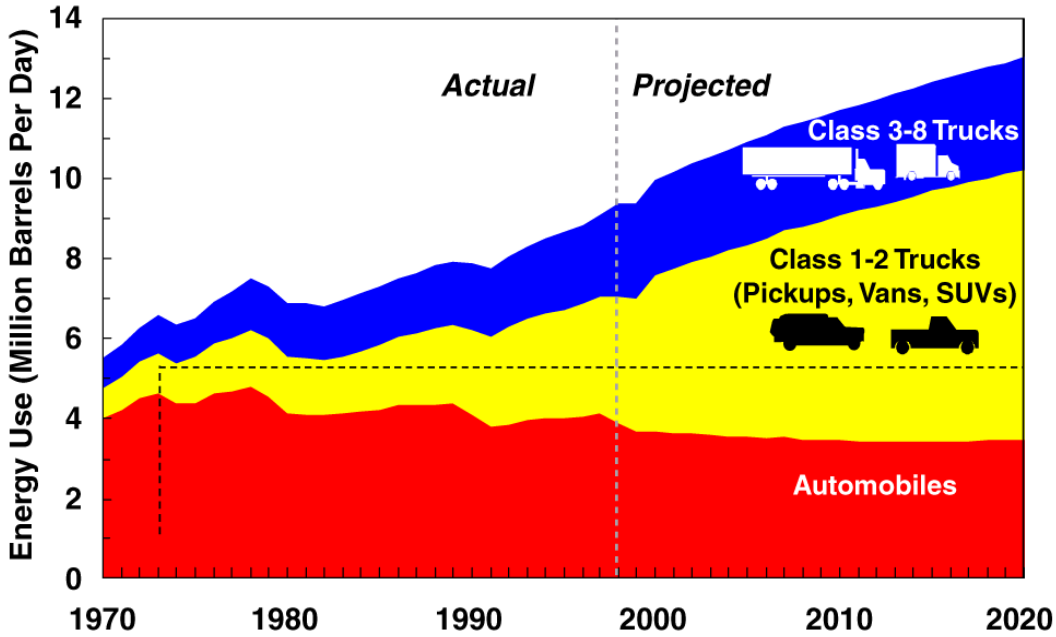


Fig. 2.2. Trucks account for increasing highway transportation energy use. *Sources: EIA Annual Energy Outlook 2000*, DOE/EIA-0383 (2000), December 1999. *Transportation Energy Data Book: Edition 19*, DOE/ORNL-6958, September 1999.

Questions Remain about Diesel Engine Potential to Achieve Future Tier 2 Emissions and the Resulting Fuel Economy Improvement

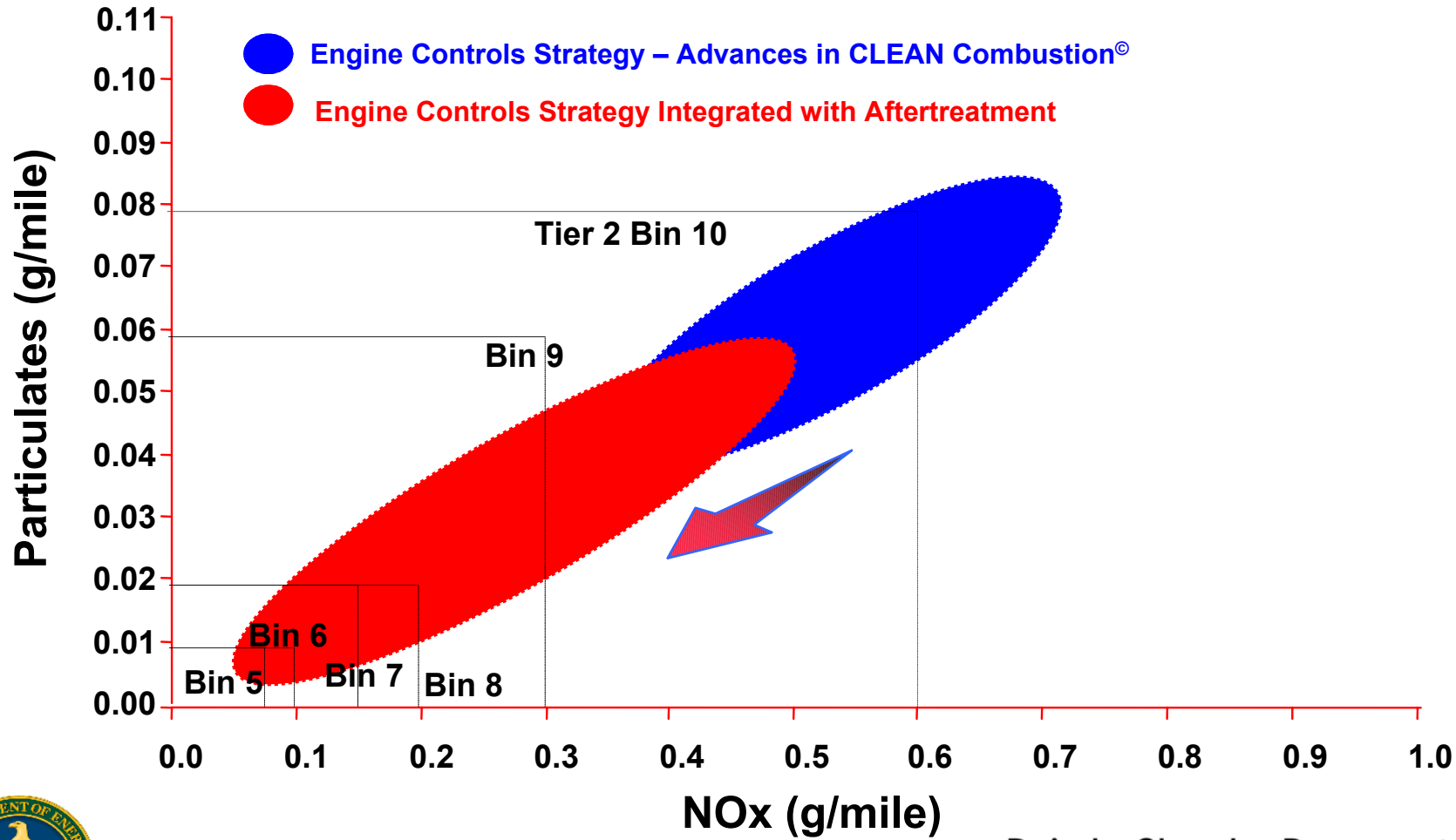
Summary

- Tier 2 Emissions Levels Achievable For Light Truck / Sport Utility Vehicle and Passenger Car Applications with Integrated Diesel and Aftertreatment (CSF + Urea based SCR) System
  - → Significant Fuel Economy Benefit Over Gasoline Engine
- Requires Low Engine Out Emissions
  - → Advanced Combustion Strategies (e.g. DDC's CLEAN Combustion©)
- Development Methodology Included Integration of Experimental and Digital Tools
- Experimental Development Test-beds
  - → Steady-state Dynamometer
  - → Transient Dynamometer
  - → Chassis Dynamometer

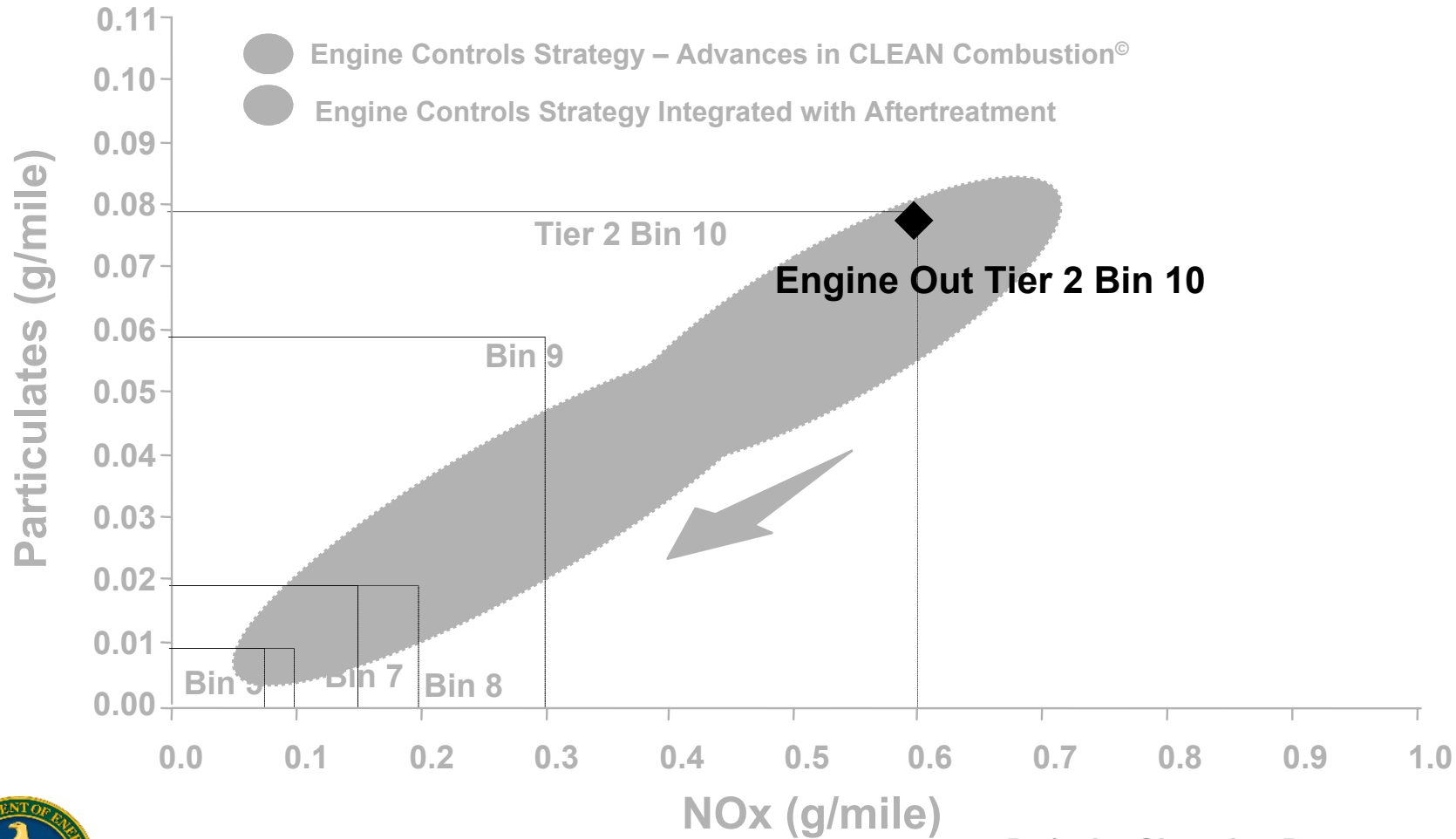
Summary (continued)

- Tier 2 Technology Demonstrated but Several Technical Challenges Remain - A Few Inventions Will be Required for the Overall Vehicle Package
  - → Increased System Complexity
  - → Sophisticated Controls Technology
    - ✓ Soot Filter Regeneration Strategy
    - ✓ Reductant Injection Strategy
  - → Infrastructure
    - ✓ Low Sulfur Fuel (<15 ppm)
    - ✓ Reductant
  - → Measurement Techniques & Emissions Variability at Extremely Low Tier 2 Levels
  - → Effect of Aging or Device Variability on Aftertreatment Performance
  - → Reductant-Exhaust Mixing Quality
  - → Fundamental Aftertreatment Data
    - ✓ Bench Reactor; Micro-kinetic

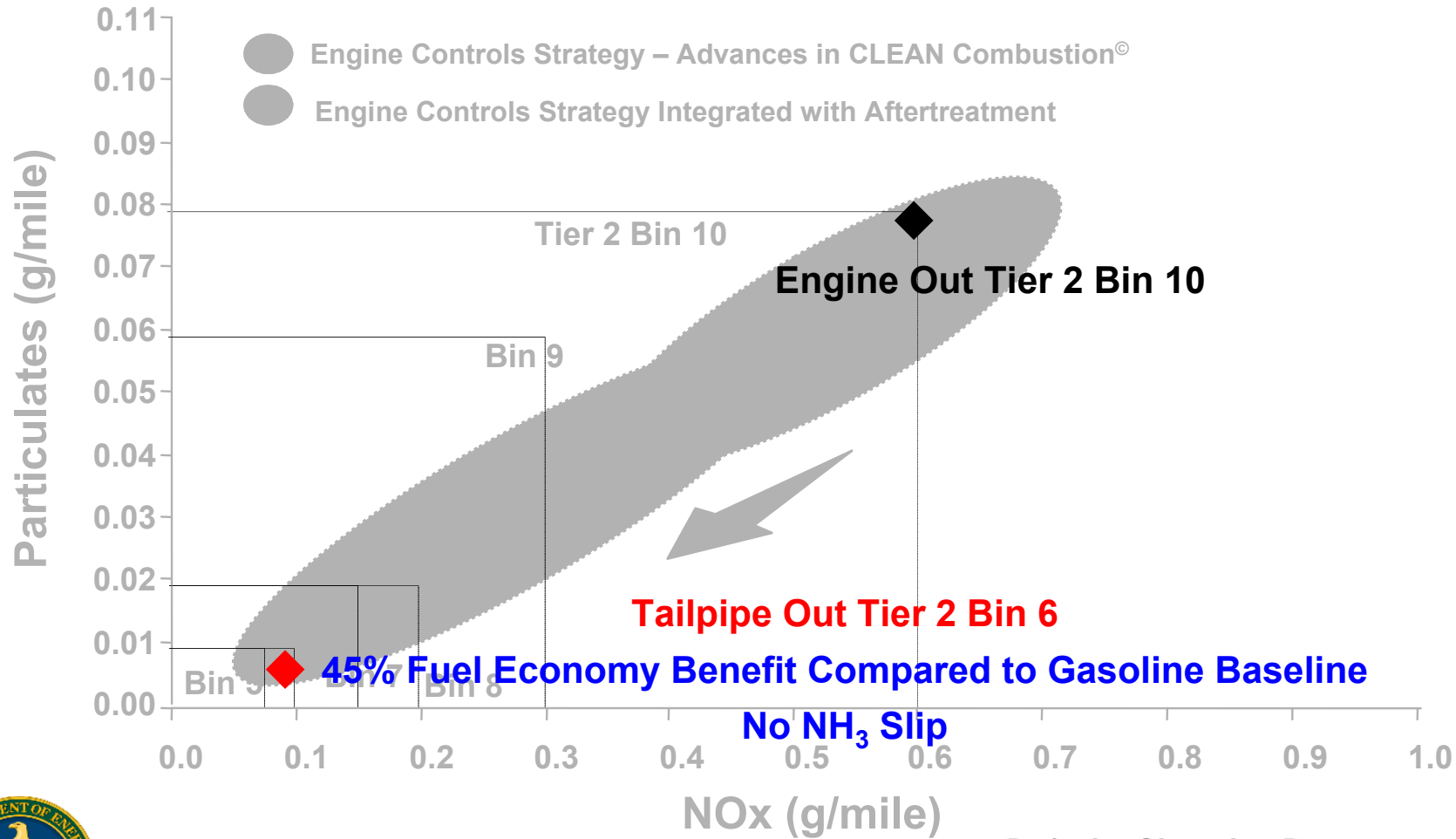
Integrated Emissions Reduction Roadmap



Integrated Emissions Reduction Roadmap
Light Truck / SUV Platform



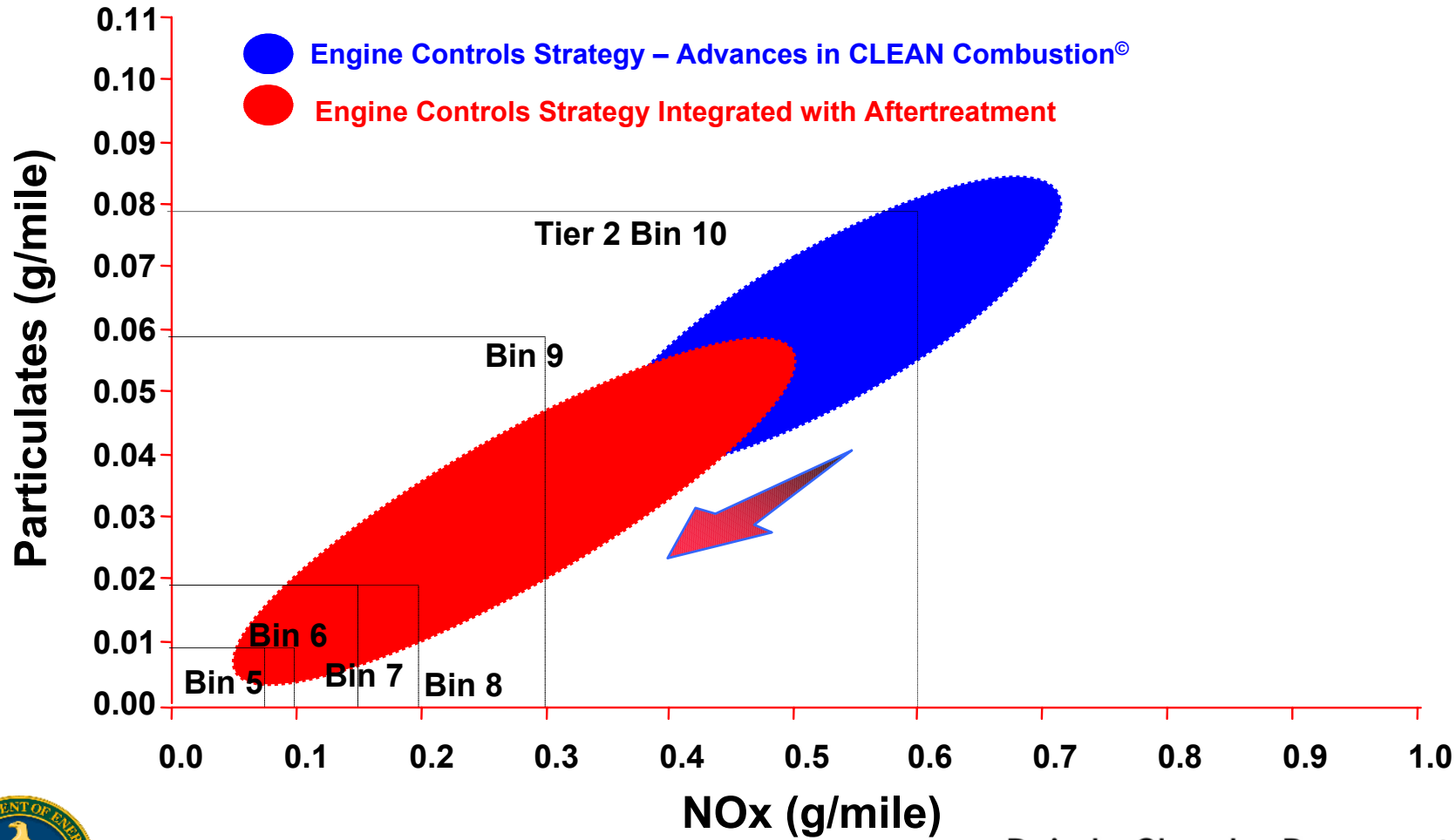
Integrated Emissions Reduction Roadmap
Light Truck / SUV Platform



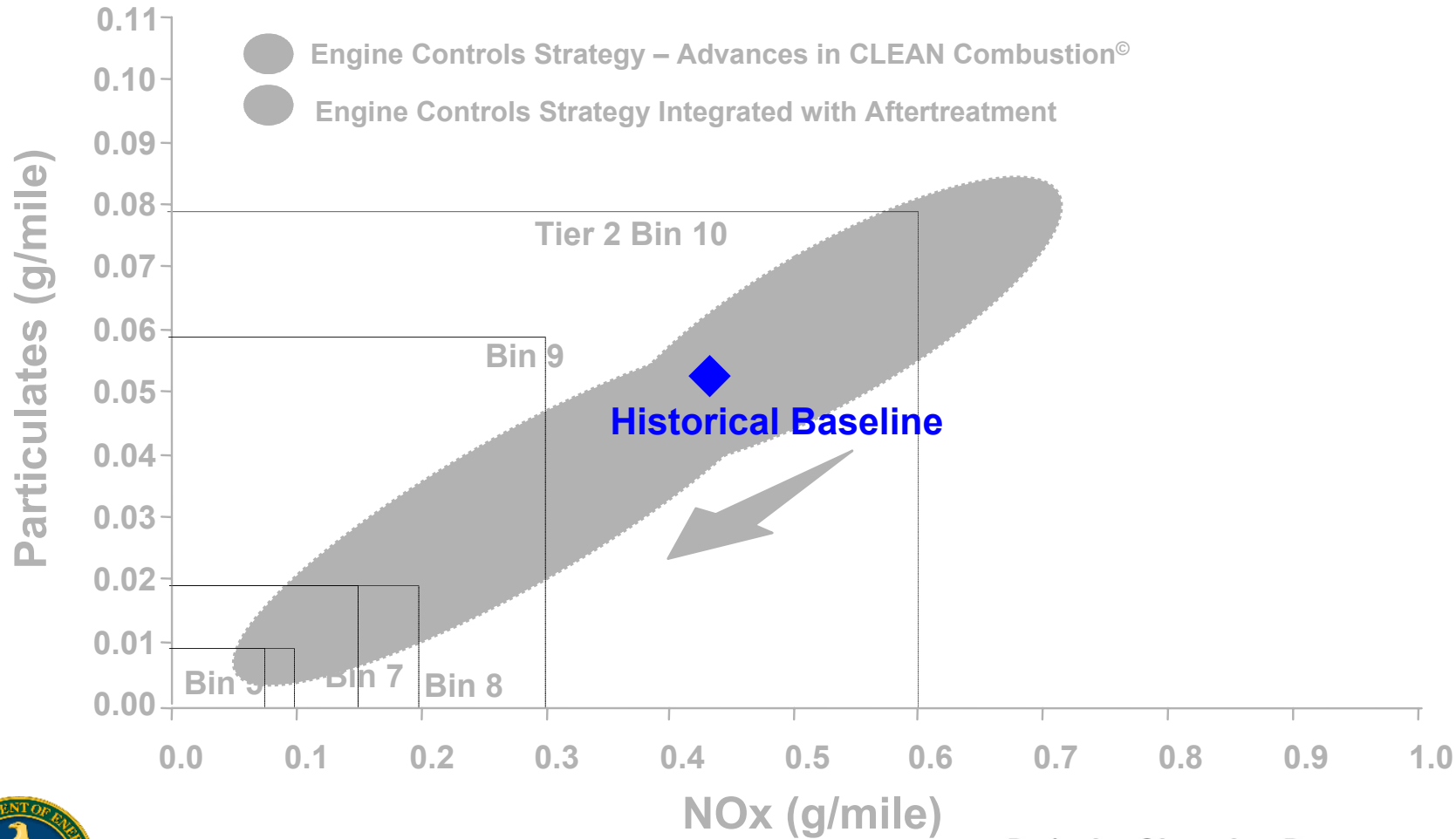
DAKOTA Ride & Drive

2001 Dakota Quad Cab Sport 4 x 2
Re-powered with DDC DELTA 4.0l V6
Twin VG Turbocharged, Common Rail Injection
235 hp @ 4000 RPM

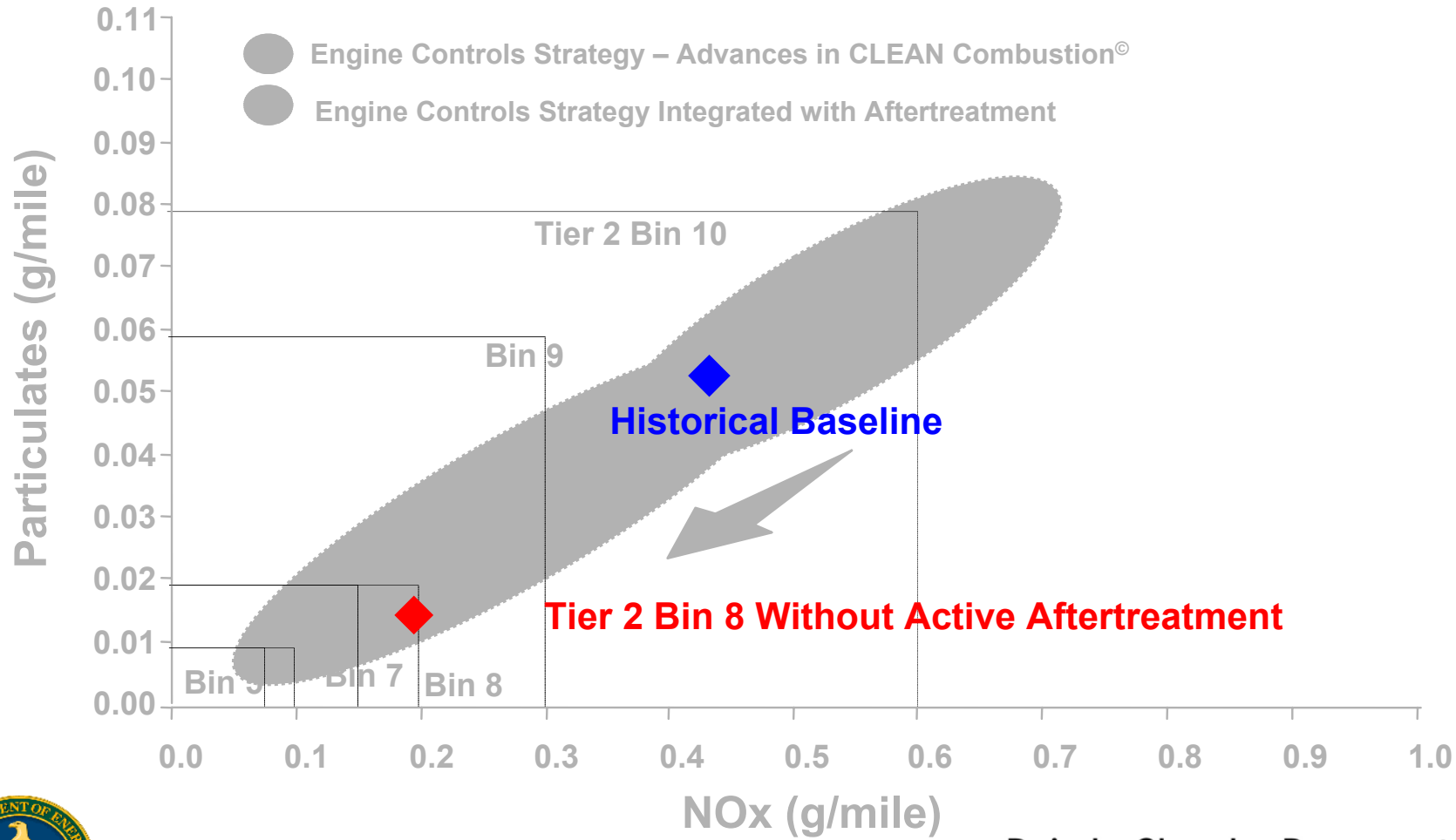
Integrated Emissions Reduction Roadmap
Light Passenger Car Platform



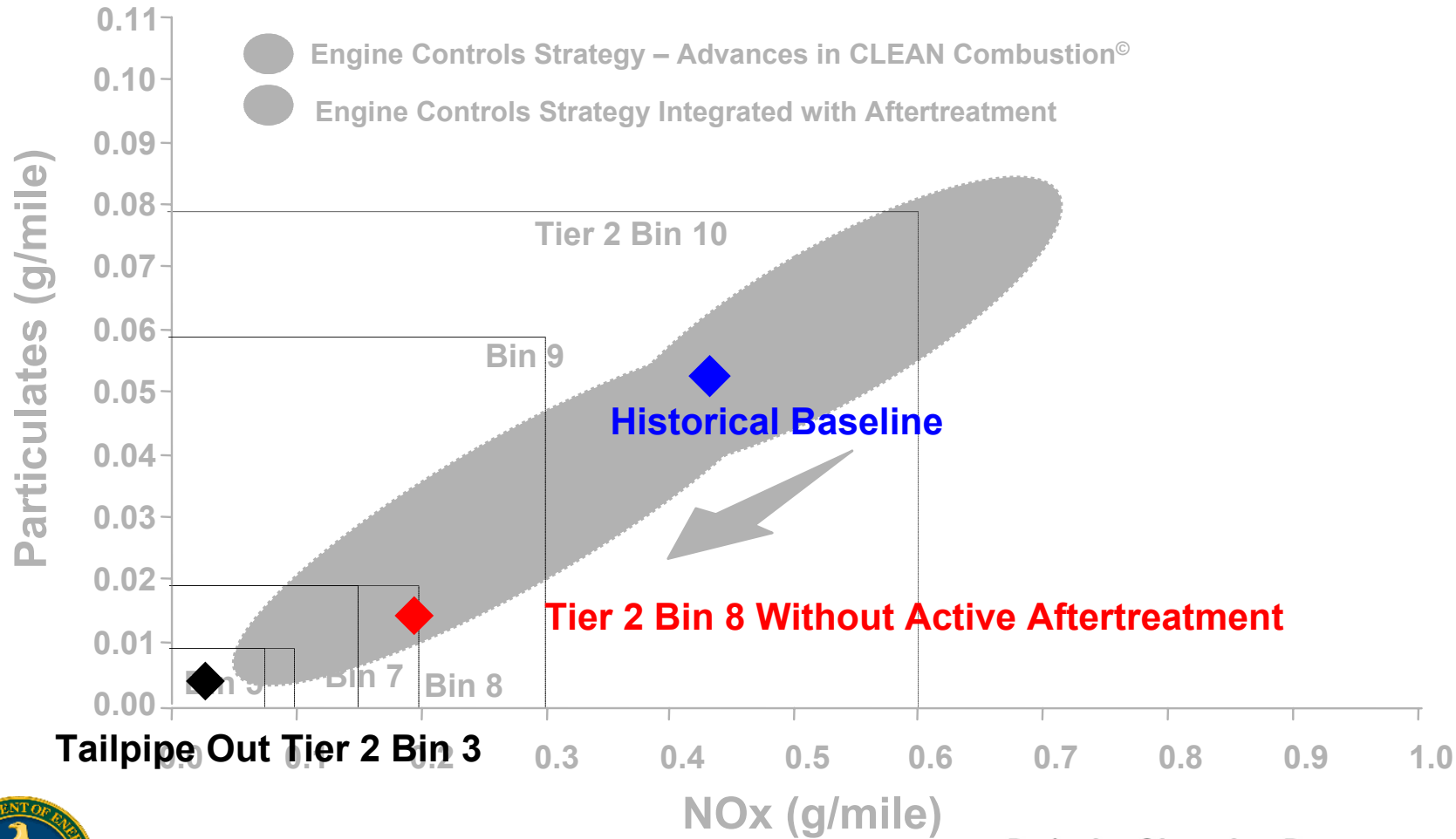
Integrated Emissions Reduction Roadmap
Light Passenger Car Platform



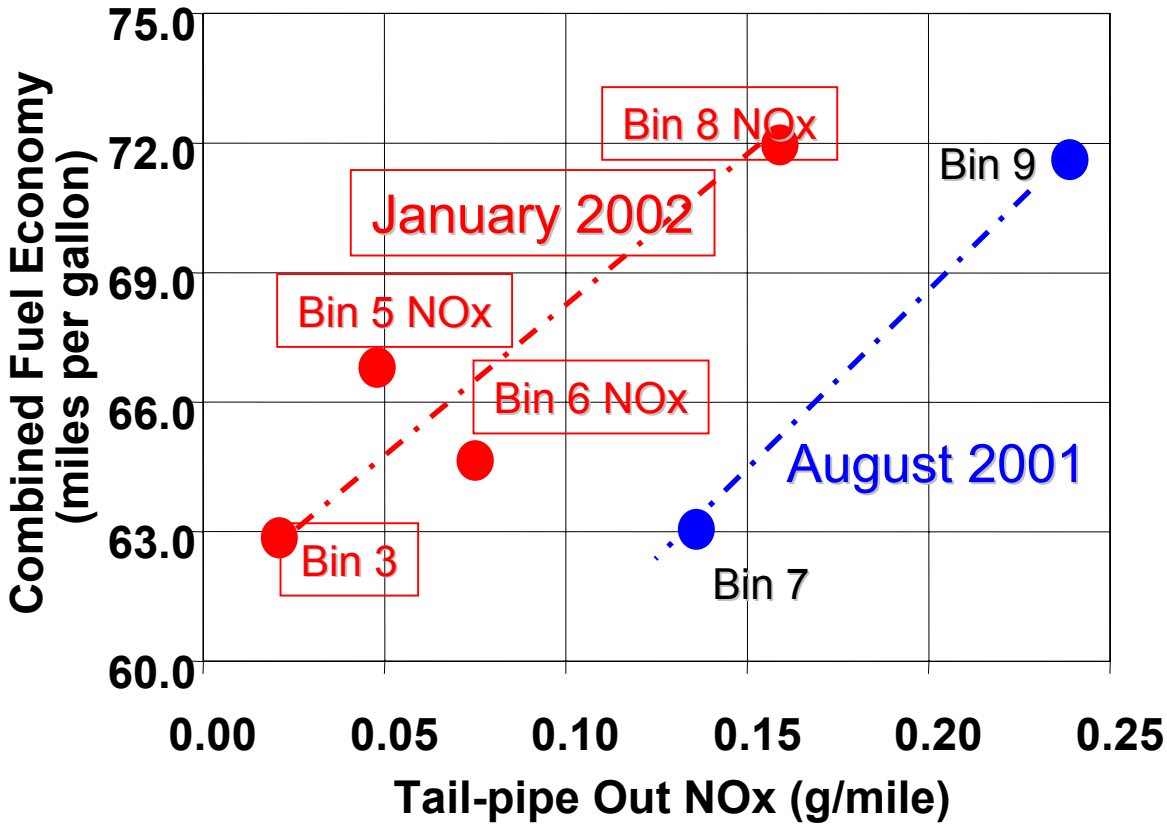
Integrated Emissions Reduction Roadmap
Light Passenger Car Platform



Integrated Emissions Reduction Roadmap
Light Passenger Car Platform



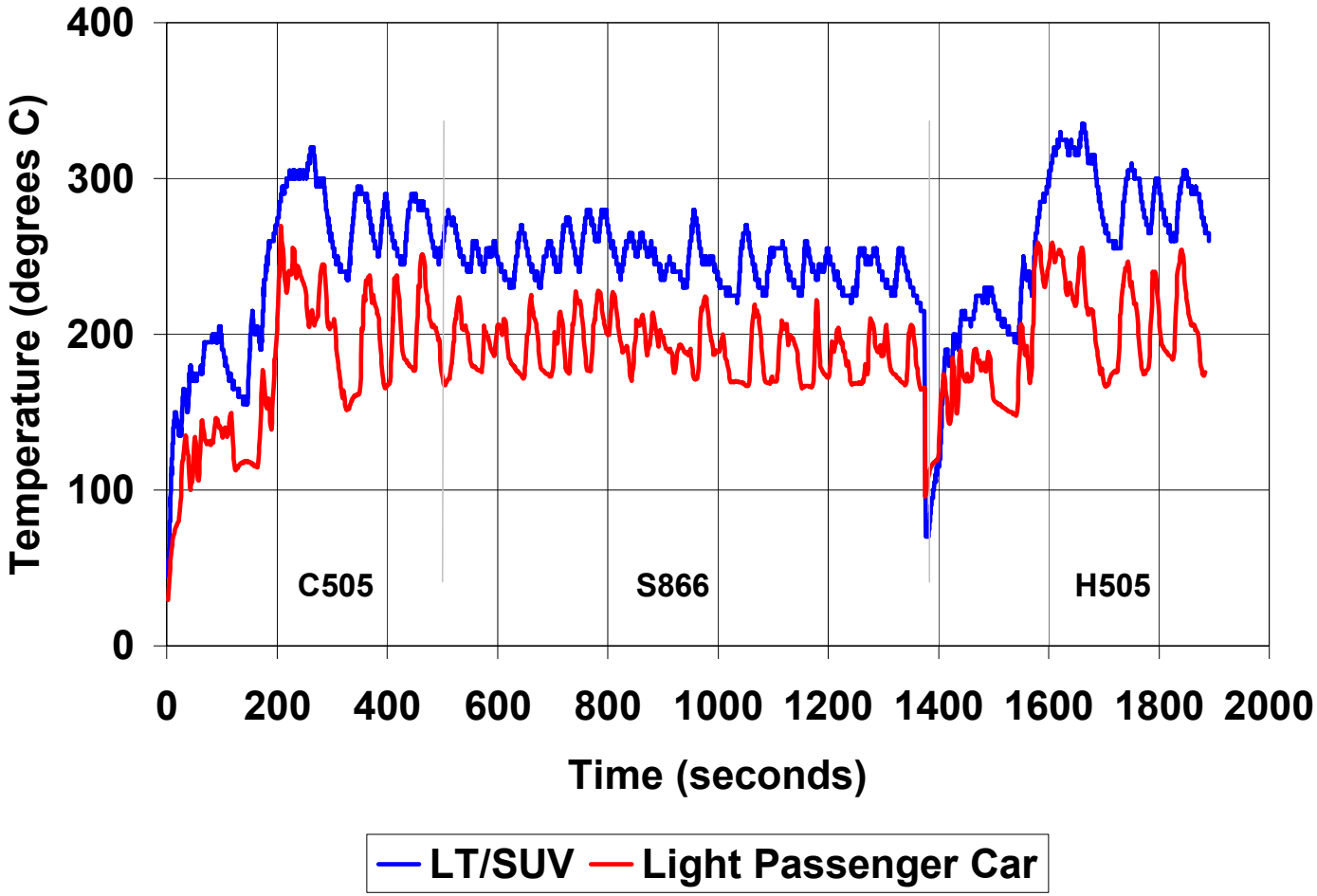
Fuel Economy Recovery Evolution
Light Passenger Car – FTP 75



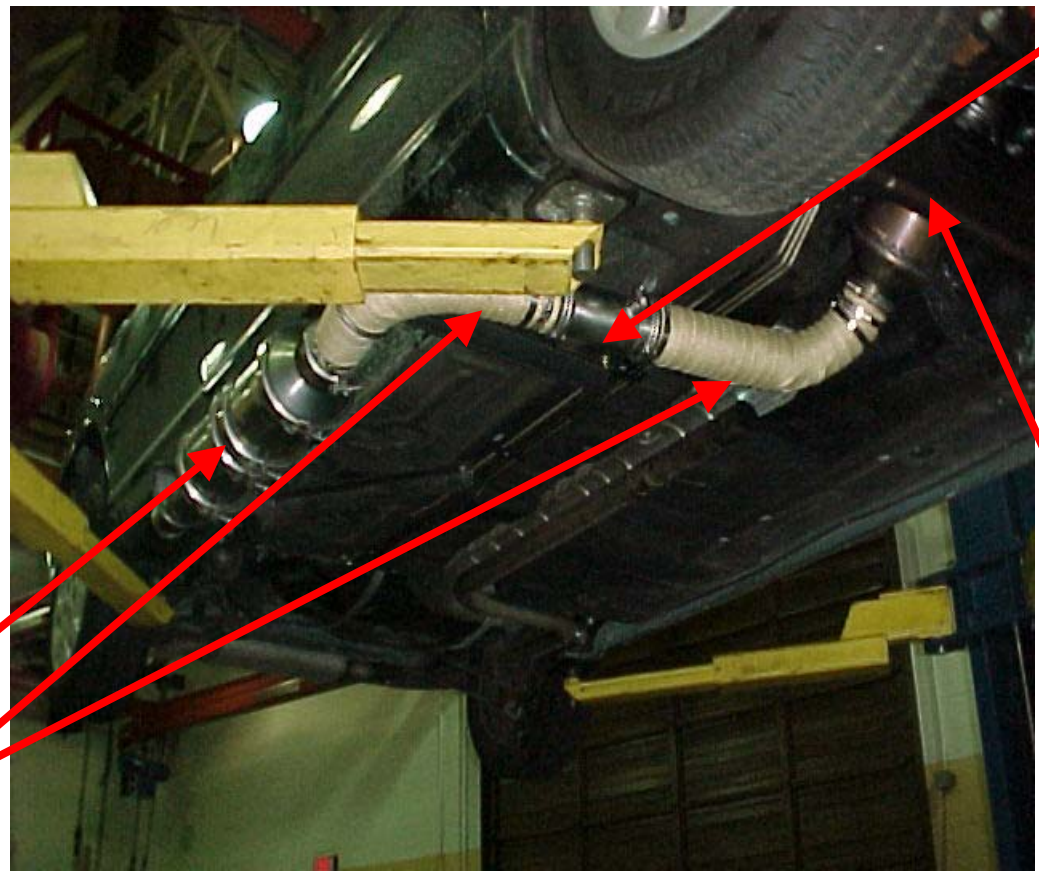
January 2002 Data Demonstrates MPG can be Selectively Recovered

Soot Filter Inlet Temperature - FTP 75

50º C ~ 75 º C Exhaust Temperature Increase with LT/SUV



Light Passenger Car Platform



PNGV Mule Vehicle

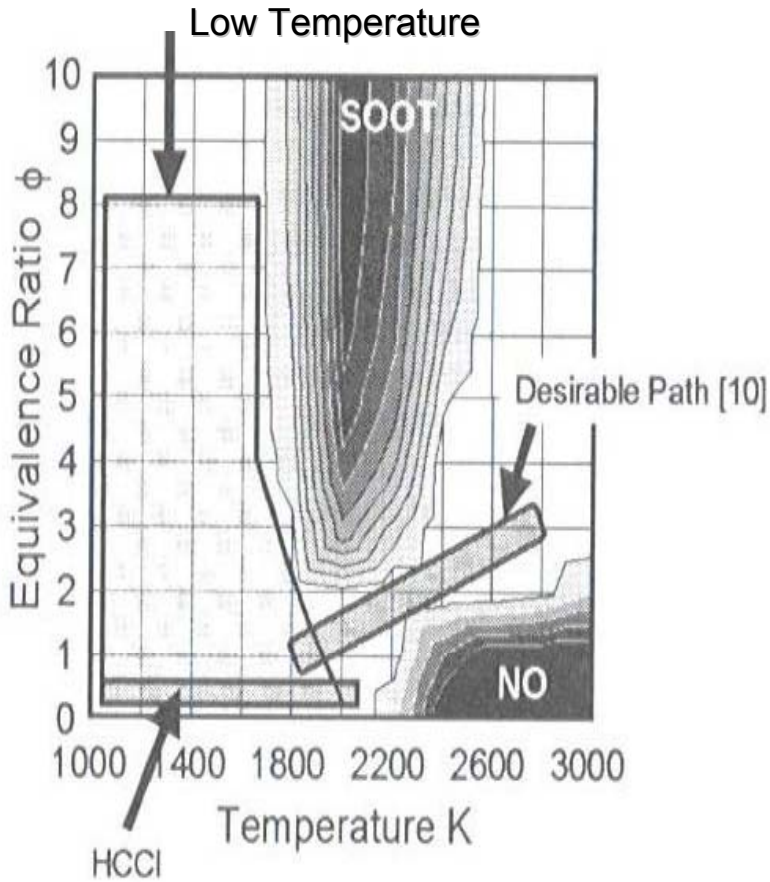
DDC Advanced Combustion CLEAN Combustion©

Diesel Fuel Based

- Demonstrated Results over Multiple Engines / Platforms
- **C**ontrolled Combustion
  - →Stable HC and CO
- **L**ow **E**mission
  - →Simultaneous NOx and PM Reduction
- **A**ftertreatment **N**urturing
  - →Integration with Passive and Active Aftertreatment

→CLEAN Combustion©

Comparison of CLEAN Combustion© to Idealized Combustion Strategies



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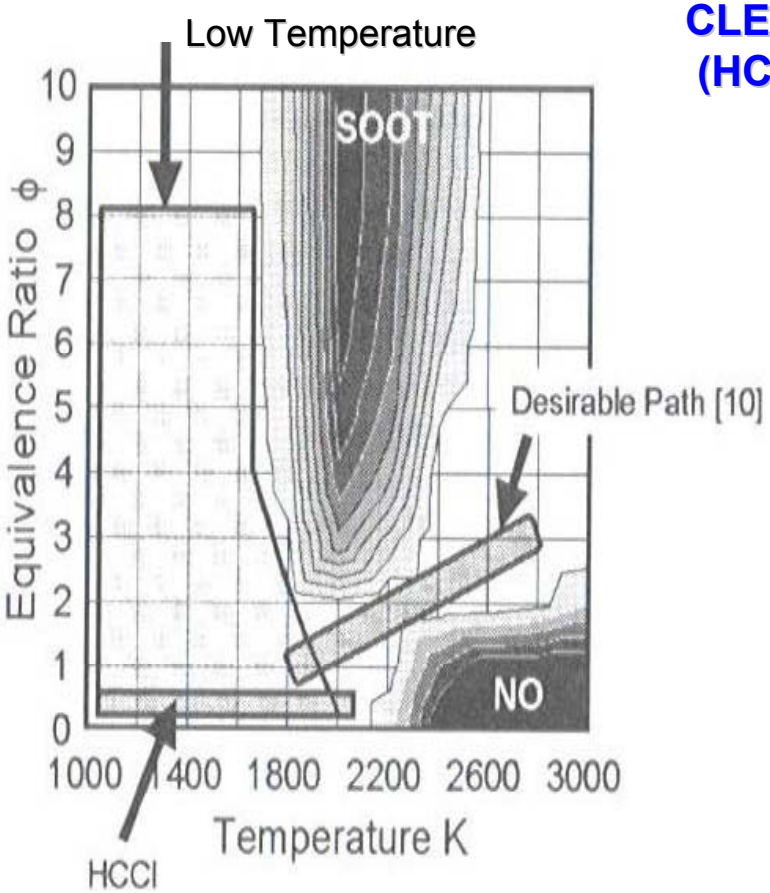
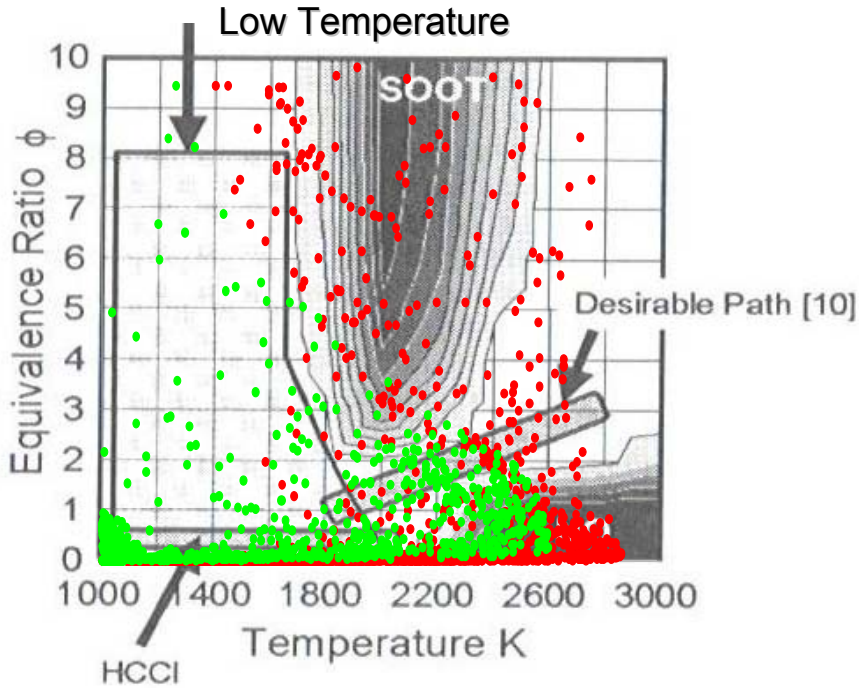


CLEAN Combustion© Combines Elements of All 3 Modes (HCCI, Low Temperature and the Intermediate Path)



Local In-Cylinder Conditions at Max ROHR Condition

CLEAN Combustion©

Conventional Combustion

Requirements and Technical Challenges

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- Sophisticated Controls Technology
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  - → Reductant Injection Strategy
- Infrastructure
  - → Low Sulfur Fuel (<15 ppm)
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Acknowledgments

- DOE-OTT
- Engelhard Corporation
- Fabien Redon
- DDC Engineering Technologies Team